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Signature of Translator

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Battery, in particular micro battery and its production by means of wafer-level technology

The present invention regards micro batteries, i.e. batteries of such small dimensions, that they can be installed on printed boards and electronic circuit elements, as well as methods for their production. The batteries are made of current foil material for cathode, separator/electrolyte and anode and are contacted and encapsulated by means deriving from wafer-level packaging technology.

Microelectronic systems become smaller and smaller. In order to promote the miniaturisation and to reduce costs, complete electronic systems are produced on one chip or such chips are arranged one upon the other in three-dimensional stacks. New applications and functions (electronic grains: eGrain, smart dust and suchlike) are rendered possible if these chips dispose of their own electronic supply. Besides MEMS, that is electronic micro systems with micro mechanic components, sensors, actuators as autonomous complete systems which as a result need a battery adapted in dimensions and parameters, are developed with increasing frequency.

Small batteries with preferably producible dimensions according to the present invention (diameter of less than 10 mm, preferably less than 3 mm, respectively length/width and thickness of between approx. 0.5 and 10 mm or in every dimension) and capacities between preferably approx.1 and 100 mAh are so far only produced as coin cells. A further miniaturization, however, can't be achieved by means of this technology. With dimensions of a few millimetres the volume related energy density is small also, as the metal casing and the seal need a lot of space. There is no economic integration in micro systems. A direct connection between coin cell and semiconductor chip is not possible. The round sheet casing has a contact on each side and therefore can not simply be connected with an IC.

Li-polymer batteries are usually packed with polymer aluminium composite foils. The polymeric material has to be a thermoplastic substance so that it can be bonded at low temperatures. The seal joint has to be some millimetres broad in order to correspond to density and reliability requirements. In very thin batteries the thickness of this encapsulation has negative impacts on the overall energy density. Every type

of battery needs its own sealing tools so that for new types new tools have to be acquired which results in highly increased costs for smaller quantities. JP 2001266952 describes a method for laminating the border regions of Li-polymer batteries. From DE 010147562 A1 a device for sealing flat batteries is known. US 2003/0031926 A1 regards the arrangement of feedthroughs in polymer packages for Li-flat batteries.

A multitude of solutions has been proposed in order to deposit batteries on substrates by means of thin film procedures. PVD, CVD and reactive PVD-methods as well as pattern technologies are used. Therefore very complex new developments have to be carried out and the continued augmentation of energy density in the conventional battery production can't be used. The vacuum technological production of battery layers, in particular of the electrolyte takes very long and therefore is very expensive. Thin film batteries exceed the energy density of today's polymer batteries. The overall energy is low, however, as only very thin batteries (with dimensions of some micrometres) are cycle stable. For larger accumulating capacities many such batteries have to be stacked one upon the other, which leads again to a strong increase in costs. We know a structure of thin film batteries from US 6,558,836. US 2002/0071989 discloses the encapsulation of thin film batteries. US 6,197,450 regards the imbedding of thin film batteries in substrates. US 2002/0110733 and US 2002/0092558 describe multi-layer thin film batteries. According to the teaching of WO 01/73866 thin film batteries are deposited by ion-enhanced procedures. No tempering steps are necessary for this method, thus it can be used also for the integration on temperature-instable substrates, e.g. polymer foils.

It has also been proposed to produce micro batteries by means of print methods, for example by ink jet printers, see also WO 01/80338.

In patent literature several descriptions of how to use battery integration with the semiconductor for an effective contacting and connection to the integrated battery management are available. Thus JP 2002/291176 regards the pin configuration of the battery in the IC casing and US 6,432,577 discloses a micro battery completely integrated between two Si-chips, wherein the active masses are in Si-structures in the form of combs. It is sealed by a wafer-bond or by an epoxy gasket.

The object of the invention is to provide batteries with very small dimensions, which have a sealing/encapsulation corresponding to the density requirements of lithium batteries, wherein the sealing respectively encapsulation is supposed to add so little to the overall weight respectively overall thickness of the batteries that the overall energy density respectively capacity per volume respectively weight of the overall battery body reached is substantially not or only hardly influenced by it. The use of tools to produce the encapsulation which have to be newly constructed or changed dependant on the size of the batteries to be produced, should be avoided. The encapsulation should be designed in such way to allow the batteries, if required, to be directly arranged on an electric component or integrated in it. It is however supposed to be suitable for usual foil batteries as well, in particular in lithium technology. In a specific configuration the batteries according to the invention are supposed to be applicable for chip cards which means that their overall thickness has to be of less than 0.6 mm.

The object of the invention is solved by providing a battery including the common battery elements like cathode, anode, separator/electrolyte layer, situated in the form of layers or foils with a single layer thickness of preferably 10 µm or more, which are usually flexible, single or already laminated, self-supporting or extracted from a support carrier, on an electrically non conductive substrate, wherein the electrodes are in contact with a suitably structured current diverter layer. The battery in a first design is characterized in that it has a first covering layer of a first electrically insulating material that is stable in relation to the used electrolyte and electrode material applied from the gas phase or in form of a fluid or viscous paste, and preferably a second covering layer of either a material as defined for the first covering layer or a second electrically conductive material, as for example a metal or an alloy which was also deposited from the gas phase or in form of a fluid or viscous paste, which form(s) together with the substrate und optionally (a) further component(s) an encapsulation through which the battery is sealed respectively insulated from the surrounding environment. In a second design the elements of the battery are situated between the electrically non-conductive substrate and a second substrate and the open border areas between these substrates are closed by the one or both covering layer(s) mentioned above. The covering layer(s) have recesses or openings

connecting the current diverters of the battery with the exterior battery contacts. These recesses or openings are filled with a electrically conductive material, preferably metal and therefore completely sealed.

The single electrode or separator/electrolyte layers or foils consist of an electrochemically active or activable material, as well as if necessary a polymer matrix (e.g. frequent with common foil layers and/or with layers prestructured with print techniques) and/or further auxiliary substances. The expression "electrochemically active or activable material" covers materials which are used as active battery component, that is above all electron-conductive materials for the electrodes and ion-conductive materials for the electrolyte layers. It's not imperative that the "active" or respectively "activable" materials of the separator layers are conductive; these layers comprise or consist of materials permitting the passing through of ion-conductive fluids or respectively of the ions contained within. These materials, too, are covered with the expressions "active" or respectively "activable" materials according to the invention. The electrochemically activable materials are then activated by connecting on the battery.

The best method for applying the covering layer(s) is the so called wafer-level packaging. This means the application of method steps as used mainly in the production and structuring of contact and encapsulation layers on semiconductor chips in the wafer formation, i.e. as discoidal substrate. In particular this covers techniques comprising the application of thin and very thin layers of a fluid phase or gas phase, as coating methods (e.g. spin-on deposition, dip or spray coating of more or less vicious fluids) as well as plasma-, vacuum- and ion-enhanced depositing methods. The layer(s) applied is/are, as far as necessary, provided by means of structuring steps with openings at the spots where the current diverter contacts of the battery are situated. The openings are reclosed by inserting metal or other electronically conductive materials allowing the current conduction between current diverters and exterior battery contacts. If necessary this material can cover larger areas of the covering layers in form of a (structured) coating and thus be used as e.g. contact to further components or as connection of the rectified poles of a multiplicity or plurality of batteries on the same substrate connected parallely or serially.

A quick and easy production of a miniaturized and form-flexible package with optimized power density is rendered possible by combination of the material saving and extremely efficient foil technology in battery production, which has been highly developed and automized during the past years and the processes of wafer-level-packaging for sealing the batteries, which are faster than conventional sealing technology and are form independently applicable in universally applicable devices. In particular as far as plasma-, vacuum- and ion-enhanced procedures are concerned, many materials with very good battery characteristics and very high mechanical stability and adherence can be used.

The present invention made it possible to provide chip-sized micro systems with dimensions of a few mm^3 by means of the combination of established battery technologies and integrated casing technology. The already available substrate of the electronic circuit or respectively the semiconductor chip serve at the same time as rear side of the casing. The surface of the casing of the battery is realised by a coating (encapsulation) of only a few µm or for instance by a further substrate for an arrangement in stacks of several batteries or one battery in combination with one or more further elements one upon the other. The substrates can be e.g. Si-chips in form of active semiconductor circuits, partially electrically conductive substrates or substrates with solar cells. If two substrates are present they are contemporaneously used for the encapsulation of surface and rear side of the battery and are closed by a one or multi-layer encapsulation of the border areas between the substrates as described above. Such batteries may be used for instance for the energy supply of a semiconductor switching circuit. A combination of solar cell, battery and semiconductor chip results in a autonomous micro system. The exterior chips and the battery are connected electrically e.g. with an exterior contact structure running perpendicularly to the stack construction. In this case stacks or other arrangements of batteries in stacks one upon the other can be used, wherein the covering of one battery serves as insulating substrate for the next one.

Such a miniaturising has so far been possible only as far as thin film batteries were concerned, which are produced by vacuum technical depositing methods. This technology, however, is very expensive due to complicated procedures and installation technique and has only small capacities, as the thickness of the electrode

layer is limited to 1 m, whereas the electrode layers in the batteries according to the invention is at least 10 µm thick and can be realized in wide areas, as the single battery foils can be produced in various thicknesses. Preferably the single layers are up to 50 µm thick, if necessary even more. The covering on the other hand can be kept extremely thin so that the achievable capacities per volume unit of the overall battery are very low.

In the following the invention is to be further described by means of figures and design examples, wherein fig. 1 to 8 present the production of encapsulated batteries in a first design according to the invention, wherein

Fig. 1 shows a substrate with hermetic feedthroughs and applied metallization from above (fig. 1a) and from the side (fig. 1b), which is to be used as exterior contact for the only one or lowest electrode and therefore as current diverter for the first electrode (if it has no additional current diverter of its own) and is to be used besides as contact site for the transmission of current from the second electrode,

Fig. 1c shows how several of such metallizations can be arranged in order to produce a plurality of such batteries on a substrate,

Fig. 2a and 2b show the same substrate as fig. 1a, 1b with the metallization as well as a first electrode,

Fig. 3a and 3b show the substrate provided with the components according to fig. 2a and 2b as well as a separator electrolyte layer,

Fig 3c illustrates a substrate with the same components as shown in fig. 3a, wherein the contact site for the transmission of current from the second electrode doesn't have the form shown in fig. 1 but that of a frame which can serve as annular contact for an area covering metallization,

Fig. 4a and 4b show the substrate provided with the components according to fig. 3a, 3b as well as a counter electrode,

Fig. 5a and 5b show the substrate provided with the components according to fig. 5a and 5b as well as a metal foil as upper current diverter,

Fig. 6a and 6b show the substrate provided with the battery components according to fig. 5a, 5b, covered by an encapsulation layer,

Fig. 7a shows the configuration illustrated in fig. 6a, 6b, the encapsulation layer of which has been structured such that a contact site of the upper current diverter is uncovered,

Fig. 7b shows a substrate provided with several battery structures according to fig. 6a, 6b, with the encapsulation layers of several battery structures opened at the same time,

Fig. 8a shows the configuration illustrated in fig. 7a, the current diverter contact site of which is occupied with a metal layer, which establishes a contact with the contact site connected to second feedthrough,

Fig. 8b shows the configuration illustrated in fig. 7b with the open current diverter contacts of all four battery structures covered with a metal layer,

Fig.8c shows a variant to fig. 8a, with the metal layer not only existing in the area of the contact site but completely covering the whole battery,

Fig. 9a and 9b illustrate the production of encapsulated batteries in a second design according to the invention, wherein

Fig. 9a shows a prefabricated, complete battery foil stack on a substrate, and

Fig 9b illustrates the readily encapsulated battery.

Furthermore the figures illustrate:

Fig. 10a and 10b the production of an opening towards the separator/electrolyte foil in the encapsulation for subsequent filling in electrolyte fluid,

Fig.11 a design of the encapsulated battery according to the invention, with the upper current diverter as persistent metal sheet, serving simultaneously as protective covering,

Fig.12 is a battery arranged between two non-conductive substrates according to the present invention, and

Fig. 13a and 13b an alternative proposition to fig. 10 for filling in electrolyte fluid via the back side of the battery.

Starting point for the generation of the encapsulated batteries according to the invention is in a first design of the invention a foil battery produced according to the common methods with one or two external current diverters, the active masses of anode and cathode and the electrolyte, for example and preferably a high energy density Li-polymer battery, which can be produced with large area from roll to roll. In a second design, it is started from the individual electrodes and electrolyte layers or foils as well as the current diverters, which are hold on carrier layers or used as self-supporting layers. The latter variant will be described at first in the following in reference to the figures 1 to 8, namely for batteries which are disposed on a substrate and which are provided on their surface as well as laterally with a very thin encapsulation:

In an insulating substrate 1, which can be e. g. a Si-wafer, the system carrier foil of a chip card or a flexible and relatively thin polymer substrate (preferably with a thickness of about 20 to 100 µm), are fabricated battery contacts 2a, 2b for both poles in form of a metallization, see fig. 1. The contacts for the further transmission can be designed in any form as needed. The substrate possesses in the illustrated design hermetically sealed feedthroughs 3, for leading the battery contacts through to the other side. Alternatively, these can e. g. be contacts, which lead through a surface insulation of the semiconductor, for contacting on the subjacent wiring, or the

contacts can be lead further laterally through conducting channels or metallizations on the substrate surface or can be lead to another component.

The metallization is performed by means of a suitable method of which the one skilled in the art disposes. Examples are sputtering, vapour deposition, galvanic reinforcement. Alternatively, a thin metallic layer can be glued on the substrate. As metal, the one skilled in the art uses the one that would be used in conventional batteries as the diverter in the form of meshes or sheets. The metallization is performed either as a persistent layer, which is structured subsequently or by a directly structuring deposition, e.g. screen printing or a deposition method such as sputtering, vaporization by using suitable patterns.

As is shown in fig. 1c, the metallization can be structured such that a plurality of batteries and their contacts are disposed simultaneously on a substrate, e.g. in a rectangular or symmetrical arrangement as shown. The structuring can be carried out chemically or physically, e.g. by means of wet or dry etching, e.g. reactive ionic etching, or by means of a semi additive method.

In fig. 2 is shown the next step, in which the first electrode 4 is laminated on the battery contacts. In this design, the battery contact can simultaneously take the function of the lowest current diverter layer, if needed or desired (e.g., if battery elements or electrodes, respectively, are used which are already prelaminated provided with own current diverters), an additional current diverter between the metallization and the first electrode can be present or be deposited. The electrode layer (anode or cathode) can e.g. be deposited on a support carrier resp. carrier foil and as needed be structured already before being deposited in an appropriate manner; it can however as well be self-supporting. The electrode is made from the electrode material which is suitable therefor, as it is known in the state of the art. The electrode material can be present in combination with an organic matrix and/or with different functional additives, e.g. for increasing the conductibility, or, in case of sufficient flexibility of the used inorganic material, without additive. The deposition which has been conducted if necessary on a support carrier can be effected with any method, e.g. by laying on a paste or by means of printing methods. The layer can first be formed as persistent and be subsequently structured as required, e.g. in a plurality

of rectangles, as e.g. needed for the example of the fig. 1 to 8. The structuring is effected e.g. by means of subtractive removal from the support carrier, which can be achieved by means of means of mechanic methods such as scratching, water jet processing, laser processing, chemical etching or the like. Alternatively, the electrode layers can be deposited by means of a printing method such as screen printing immediately in the appropriate form. Subsequently, the electrode is laminated on (or, in more rare cases, adhered with an electrically conductive glue), and the support carrier is, as far as present, removed. In case multiple batteries are disposed on the substrate on the same level, this step is preferably carried out simultaneously with all battery structures. By the term "laminate on" is to be understood first of all a method in which the layers or foils are deposited under pressure and at elevated temperatures on the respective support. Especially if organic thermoplastic polymers are present in the layers, a strong conjunction with the adjacent layers can be formed.

In an alternative design, e.g. chip-sized electrodes are stamped out and (with or without support carrier) are laminated or bonded individually by means of a chip bonder directly on the substrate with current diverter.

Fig. 3 shows the depositing of the electrolyte or respectively the separator electrolyte layer 5. This layer can be a neutral, absorbent material in respect of ionic conduction, which is later filled with electrolyte solution, or it can be a solid electrolyte, which functions with or without additional ion conductive fluid as an electrolyte layer, as known from the art. This layer can either be self-supporting and be structured on the electrode layer 4 after deposition, or a prestructuring is carried out on the support carrier. The methods which can be used therefor are the same as those for the deposition (first of all laminating, if necessary gluing as well) and which can, if necessary, be used for the structuring of the first electrode and which are described in the foregoing for said electrode. Instead of that, also photo-structurable electrolytes can be used, which are deposited all over the surface and are subsequently structured by exposing to light and developing in the size of the individual batteries.

Fig. 4 illustrates the deposition of the counter electrode 6. The fabrication is carried out with the same procedure steps as that of the first electrode. The electrode materials are selected by the one skilled in the art in a suitable manner.

As can be seen from fig. 5, the deposition of the upper current diverter 7 is carried out subsequently. This can be effected e.g. by laminating on prestructured metal foils, which are, if necessary, again deposited on a support carrier, or by structuring of a persistent, self-supporting layer, or also even structured deposition (vaporization, screen print, and other methods) directly onto the counter electrode. In respect of the last-mentioned methods, it is referred to the description concerning the deposition of the first battery contacts (2a, 2b).

In Fig. 6, the deposition of an encapsulation or, respectively, a passivation layer 8 is illustrated.

Before deposition of the passivation, a drying of the battery substrate can be carried out if necessary in an inert gas oven. The passivation generally is decisive for the reliability and shelf life of the battery. Thus, in the case of Li-ion batteries, no moisture, no oxygen, nitrogen or CO_2 may come into contact with the electrodes or the electrolyte. Therefore, the coating has to be such that it possesses a very low permeation rate for these species. Requirements concerning the tightness can in special cases be realized with a single layer; in general, a multiple-layer structure is however recommended, especially a structure consisting of two layers. In the latter case, only the first layer must be electrically insulating, whereas in the further layer stack also metals can be employed.

Of course, every layer of the passivation must be deposited with procedure steps where the substrate temperature is small enough not to compromise the battery. It is in general recommended to substantially maintain a maximum temperature of 80-120 °C and to exceed it only during a short time. However some battery systems are especially designed for higher temperatures and are thus suitable for proceeding temperature up to about 200 °C.

Due to the sensitivity of the Li-batteries, the processes described in the fig. 1 to 5 should all be carried out in the fabrication of such batteries in inert gas conditions or in the vacuum. For wafer processes, the common handling machines and equipment which work under vacuum can be used. As far as the invention shall be applied in less sensitive batteries, these requirements are of course not obligatory.

Since during the first cycles a gassing of the battery can occur, it is recommendable to fill the battery at first with additional fluid electrolyte, if this is provided, then to form under inert conditions (e.g. in the drying room) and to store in the vacuum for eliminating all gas rests and only to encapsulate in subsequence to that. For this purpose, all batteries on a substrate are contacted on with a contact adapter. In primary batteries as well as in secondary batteries a predeterioration of the battery (storage at elevated temperatures) is possible, before the passivation is fabricated. An alternative to this approach is described in relation with the description of the fig. 10.

For the or at least for the first covering layer, a material must be used which is resistant in relation to the used electrolyte and the used electrodes. The material will be deposited from a more or less viscous, fluid phase or the gas phase. E.g. the vapour deposition of parylene, the plasma polymerization of different inorganic-organic barrier layers, the deposition of Al_2O_3, SiO_2, SiO_yN_x at relatively low temperatures (recommendable: at or below 80 °C), spin-on deposition, dipping and spray coating of epoxy resins and the UV curing thereof, but also of other materials, which are electrically non-conductive, temperature resistant and structurable, the latter preferably being photo-structurable by means of UV light or other radiation sources.

The first or only passivation or encapsulation layer should possess a good adherence to substrate and battery and have a good mechanical stability and elasticity for being able to absorb extensions which occur due to minor volume changes of the battery in cycling or storing. The thickness of the passivation is advantageously between 1 and about 100 µm, especially preferred between 2 and about 30 µm. Since in many cases it is inevitable that the layers have pores, for inhibiting eventual leaks on the first passivation or encapsulation layer, preferably at least one second layer is

deposited. Here, also electrically conductive layers can be used, which can, as described above for the diverter layers, be deposited on the first passivation layer. Preferably, a vaporization with aluminium is carried out, but however also a sputter or other method and/or another metal or a mixture/alloy of metals can be employed. If necessary, a second insulating passivation layer of the above-described materials can be deposited instead. If needed or desired, one or more electrically conductive and/or insulating layer/s can follow. Reasonable is a layer sequence of at first two electrically insulating layers, on which first a metallization and then a finishing polymer layer are deposited.

If the deposition of the hermetic encapsulation is carried out in vacuum, the contact pressure which is favourable for the function of the battery is achieved after the outward transfer by the air pressure.

The encapsulation is carried out preferably by applying of a persistent layer over the lateral and upper surfaces of the battery, so that the encapsulation layer creates together with the substrate a complete and tight encapsulation around the battery elements. In this preferred design, ways must be created subsequently for the contacts. As illustrated in fig. 7, there are at first fabricated openings in the encapsulation layer, which uncovers the current diverters 9. In case of neat spatial arrangement, only one opening is needed. Therein, it is favourable when the current diverters 9 extend over the battery itself, such that in e.g. a mechanical uncovering of the contacts through the opening 10, which can be carried out by a saw cut or the like, the active areas of the battery can be maintained completely encapsulated.

The opening of the passivation can be carried out by any suitable method. Favourable are for example plasma processes such as reactive ion etching, ion bombardment, wet chemical etching or mechanical methods (milling, wafer saw, water jet) or a processing by means of laser. As the structure is stacked, it is also possible to apply multiple methods one after the other. In this way, e.g. also the uncovering of a major area of the metal in comparison to the insulator layer in an encapsulation which contains a metallic layer can be achieved, for inhibiting electric shorts during fabrication of the contacts. If for example the opening is obtained by a wafer saw or a mill, persistent channels 10 can be formed which open the contacts of

even multiple batteries, as is shown in fig. 7b. In wet or dry etching, a lithography step for the transfer of the contact image is necessary. Here, pattern processes can easily be used, as only two contacts per battery are respectively needed and thus, all tolerances of the justification and dimensions of the individual batteries can easily be compensated.

Over the obtained openings, subsequently an electric contacting on is carried out, as shown in fig. 8. For that, metals 11 are deposited and structured, which create a conjunction between the current diverter contacts 9 and the real battery contacts 2a, 2b or 3. This can be carried out by vaporization or sputtering of metals or alloys such as Al, TiW, Cu. The structuring is carried out in a known way, for example by lithography or suspension patterns. Also possible is the bonding of wire bridges.

A better hermiteicity of the encapsulation can be achieved when the battery is encapsulated in a metal layer as completely as possible. For that, as is shown in fig. 3c, not only a contact is applied for the upper electrode in the lower metallization layer on the substrate, but a frame shaped metallization 2b' is laid around the metallization 2a (fig. 1). On the electrically insulating passivation layer 8 (fig. 6) then not only a small contact flag 11 (fig. 8a) for the upper contact is applied, but a complete metallization, which covers all of the battery and which connects with the lower metallization frame 2b' at the edge, as shown in fig. 8c. Except the small area of the feedthrough of the lower electrode contact, the battery is almost completely encapsulated in a metal layer, which substantially reduces the permeation rate for gases and fluids of the environment.

In fig. 9 is illustrated an alternative fabrication of the total system, wherein the electrochemically active elements (anode, electrolyte, cathode), if necessary already together with the current diverters (in fig. 9 represented as white bars without assigned numbers) are inserted into a prelaminated foil stack. This foil stack is designated as 14 in fig. 9a. The stack is separated into batteries of suitable size, preferably in chip-sized individual batteries, and these are applied on the carrier substrate. This can be carried out by a current method, for example by laminating or gluing. Instead, the foil stack can be deposited all over the surface on the carrier substrate or on the wafer and subsequently be separated into batteries of suitable

size, e.g. in chip size. Again, current methods can be employed, for example milling, wafer sawing, water jet processing, laser processing or the like. Herein, it is recommendable that, as far as possible, on at least one battery side, bevelled edges 15 are fabricated. Subsequently, the complete battery stack is encapsulated by means of layer deposition as described above in connection with the descriptions for fig. 7. For the methods for applying the encapsulation layer(s) as well as the materials which can be applied therefore, the foregoing is to be applied. If necessary, also different materials can be used on the flanks 16 and on the upper surface 17. Thus, the border insulation 16 e.g. can also be carried out through dispensing. In this method, a toric polymer layer is applied from a cannula, which is moved alongside all battery edges. The material is thereby applied such that a complete wetting of the battery border with polymer from the substrate to the upper edge of the battery is achieved. Subsequently, into these lateral encapsulation layers openings are structured as described above, which enable the contacting on of the current diverter foil. Therein, all openings are respectively lying one above the other, which belong to the positive battery contact (18) or negative battery contact (19). Subsequently, the electrical connections between the individual current diverter foils and the battery contacts 2a, 2b, 3 are fabricated by applying structured metal layers 11, also as described above.

In case the structuring of the contact openings is carried out by means of a pattern lithography, very accurate tolerances should be maintained in direction of the current diverter foils which are lying one over the other. Therefore, a structuring of the chip batteries on the common substrate with high accuracy is favourable. When mounting together batteries on the substrate which have been individual before, very accurate justification precisions must be maintained. Since all batteries can be contacted on at the same side, this tolerance only has to be maintained in one direction. An example: At a thickness of the current diverter foil between 10 and 20 μm and a gradient of slope of the battery of 60°, the justification precision should be better than ± 3μm.

In fig. 10, a variant of the present invention is represented, in which the electrolyte fluid shall only be filled into the battery when the battery is already encapsulated. As it can be seen from fig. 10a, an opening 12, which reaches to the electrolyte/separator foil, can in this case be fabricated simultaneously with the

opening of the contacts (fig. 7, 10) or if desired also before or after. The closing of the electrolyte opening is carried out after filling with an additional deposition 13 of a polymer or metal, or simultaneously to the deposition of the contact metals 11 (fig. 8), see fig. 10b. Since the battery in this design of the invention is free of electrolyte fluid and thus of volatile solvents at that moment of the encapsulation, for all foregoing steps, higher process temperatures can be applied. Such temperatures are of course also possible in any case where the battery works absolutely solvent-free, that is, when it is a pure solid battery.

Alternatively, for filling the battery with fluid electrolyte, e.g. a hole 30 can be provided in the substrate 1, which continues through the lower metallization 2a (see fig. 1). This alternative is shown in the fig. 13a and 13b. After the battery has been completely assembled and encapsulated, the electrolyte is filled in from the rear side. The electrolyte spreads through the electrode layer 4 (fig. 2) and impregnates the separator 5 (fig. 3) and the upper electrode layer 6 (fig. 4). Subsequently, the hole is hermetically closed (fig. 13b). This is carried out preferably by soldering, by introducing e.g. a solder ball 31 or a polymer ball coated with solder 31 into the metallized opening and is soldered by a heat impulse. This can be realized e.g. by laser soldering. Due to the short-time introduction of heat, no heating of the battery occurs. By exact dosing of the solder amount, no solder can reach the battery or the electrolyte. Alternatively, a sealing by micro-welding, micro-riveting, or even gluing is possible. Of course two holes can be used as well, wherein the filling is carried out through one hole, whereas the air can escape through the other hole.

Fig. 11 shows an alternative structure. In this design, the upper current diverter foil has the form of a persistent metal sheet, which is simultaneously used as upper encapsulation. Solely, an electrically insulating encapsulation 21 must be applied on the edge. This can be carried out by dispensing or all other cited methods (fig. 6, fig. 9).

In fig. 12, a stacked structure, consisting of a battery 14, which is disposed between two substrates 1, is represented. The battery in this figure has multiple layerings; of course also a battery with only one electrolyte foil with two electrodes is possible. The substrates can be for example Si-chips in the form of active semiconductor circuits,

partially electrically conductive substrates or substrates with solar cells. The substrates serve for encapsulation and are closed by an encapsulation of the border area between the substrates, as described in the foregoing for batteries which are uncovered at the top. Therefore, it is referred to the foregoing descriptions concerning the encapsulation with an encapsulation layer 24, the methods and materials employed therein and those concerning the opening and re-closing of the encapsulation layer(s). The openings 18, 19 filled with metal serve for the contacting on of the individual current diverter foils. Such batteries can for example serve for the energy supply of semiconductor circuits. The combination of solar cell, battery and semiconductor chip results in an autonomous micro system. The electrical connection between the external chips and the battery can be carried out through an external contact structure 23 which is perpendicular to the stack structure.

Claims

1. Battery with an electrically non-conductive substrate (1) on which it is arranged, further comprising at least one cathode (4), one anode (6), and a separator/electrolyte layer (5) in form of layers or foils that are preformed from an electrochemically active or activable material and optionally a polymer matrix and/or further auxiliary substances, in corresponding sequence on the substrate (1), wherein the layer thickness of each electrode layer is ≥ 10 µm, at least one current diverter (7) and at least one battery contact (2, 2a, 2b) that are respectively in electrical contact with an electrode, characterized in that the battery comprises at least one first covering layer (8, 16, 17, 21) consisting of a first electrically insulating material that is stable in relation to the used electrolyte and electrode material and has been deposited from the gas phase or in form of a liquid or viscous paste, the covering layer forms an encapsulation with the substrate and optionally with at least one other component, by which the battery is sealed from the surrounding environment, and which is provided with at least one recess (11, 18, 19) that is closed by an electrically conductive material and which are connected to at least one current diverter (7) of the battery.

2. Battery according to claim 1, which comprises on top of the first covering layer a second covering layer of either a material as defined for the first covering layer or a second electrically conductive material which was also deposited from the gas phase or in form of a liquid or viscous paste.

3. Battery according to claim 2, comprising a first, a second, and a fourth covering layer made of a first electrically insulating material that is stable in relation to the used electrolyte and electrode material, deposited from the gas phase or in form of a liquid or viscous paste, and a third covering layer made of a second electrically conductive material which was also deposited from the gas phase or in form of a liquid or viscous paste, wherein the first material of the first, second, and fourth covering layer can be similar or divers.

4. Battery according to one of the previous claims, characterized in that the battery is covered by a second electrically non-conductive substrate (1) as further

component in such a manner that the open border regions between these substrates are sealed by the covering layer(s).

5. Battery according to one of the claims 1 to 3, characterized in that the battery is covered by a current diverter in form of a persistent metal sheet (22) as further component in such a manner that the open border regions between the substrate (1) and the current diverter (7) are sealed by the covering layer(s).

6. Battery according to one of the previous claims, characterized in that the substrate (1) or the substrates (1) is/are (a) silicon wafer, the system carrier foil of a chip card or (a) flexible polymer substrate(s).

7. Battery according to one of the claims 1 to 4 and 6, characterized in that at least the upper or top current diverter (7) has the form of a flexible prefabricated foil.

8. Battery according to one of the previous claims, characterized in that the battery contact (2) positioned on the substrate (1) has the form of a metallization or of a metallic layer glued on the substrate.

9. Battery according to claim 8, characterized in that the metallization or metallic layer is structured in such a manner that it forms beside the mentioned battery contact (2a) a second, from the mentioned battery contact separated battery contact (2b) for the counter electrode which is outside the encapsulation and that the substrate (1) optionally has feedthroughs (3) which lead away from both battery contacts (2a, 2b) through the substrate.

10. Battery according to claim 9, characterized in that the material of the one or of the at least one recess (18, 19) sealed with an electrically conductive material is in conductive contact by means of a layer of electrically conductive material (11) with the second battery contact (2b) or that this material (11) is a component of the mentioned layer made of electrically conductive material (11) which is in conductive contact with the second battery contact (2b).

11. Battery according to one of the previous claims, characterized in that the electrically conductive material with which the recess(es) are sealed, is a metal or metal alloy.

12. Battery according to one of the previous claims, characterized in that the first electrically insulating material of the covering layer is selected from parylene, non-conductive inorganic-organic polymeric materials with battery properties, Al_2O_3, SiO_2, SiO_yN_x, and epoxy resins.

13. Battery according to claims 8 and 11, characterized in that the second battery contact is formed as frame-shaped metallization (2b') which is laid around the first battery contact (2a), and that the mentioned electrically conductive material (11) covers the complete battery and is in persistent contact with the metallization (2b').

14. Battery according to one of the previous claims, further comprising an entry channel (30) to the separator/electrolyte layer which extends through the substrate (1) and is sealed or can be sealed from the surrounding environment (31).

15. Battery according to one of the previous claims, characterized in that the battery comprises a multiple sequence of electrodes (15) and separator/electrolyte layers in form of flexible prefabricated foils made of electrochemically active or activable material and optionally a polymer matrix and/or further auxiliary substances, wherein each a current diverter is positioned between two rectified electrodes and a separator/electrolyte layer is positioned between two counter directed electrodes, and wherein all current diverters which are in contact with the electrodes of equal polarity, are in contact with a recess (18, 19) respectively which is sealed with an electrically conductive material, and wherein the recesses (18, 19) are in conductive contact with structured metallizations in such a manner that a conductive contact is present between each the electrically rectified current diverters and one of two battery contacts (2a, 2b) and/or one of two feedthrough(s) (3) which lead away through the substrate (1).

16. Plurality of batteries according to one of the previous claims, characterized in that each battery is positioned on the same electrically non-conductive substrate (1).

17. Plurality of batteries according to claim 16, characterized in that the electrodes, electrolyte layers and current diverters of each battery are arranged in the same plane.

18. Use of at least one battery according to one of the claims 1 to 15 or a plurality of batteries according to claims 16 or 17 in a system with independent energy source positioned on a silicon wafer or chip, characterized in that the electrically non-conductive substrate (1) of the battery(ies) is part of the silicon wafer or chip.

19. Use according to claim 18, wherein the system further comprises at least one solar cell, which is preferably positioned on the opposite side of the or one of the substrate(s) (1).

20. Method of manufacturing a battery according to one of the claims 1 to 15 comprising the following steps:

(i) Providing a substrate (1),

(ii) Applying a battery contact layer (2) on the substrate (1),

(iii) Applying an electrode layer (4),

(iv) Applying a separator/electrolyte layer (5) on the electrode layer (4),

(v) Applying a counter electrode layer (6) on the separator/electrolyte layer (5),

(vi) Applying a current diverter layer (7),

wherein the steps (ii) to (vi) can be performed subsequently or simultaneously or wherein at first step (ii) and then at the same time steps (iii) to (vi) may be performed, or wherein at first step (ii) is performed and then the steps (iii) to (vi) are repeated several times simultaneously or subsequently in suitable order,

(vii) Applying a first covering layer (8, 16, 17, 21) consisting of a first electrically insulating material that is stable in relation to the used electrolyte and electrode material from the gas phase or in form of a liquid or viscous paste and optionally a second covering layer consisting of either a material as defined for the first covering layer or a second electrically conductive material which was also deposited from the gas phase or in form of a liquid or viscous paste, and optionally further covering layers of the first or the second material in such a manner that these covering layer(s)

form together with the substrate und optionally (a) further component(s) an encapsulation through which the battery is sealed from the surrounding environment,

(viii) Removing material of the covering layer(s) in such a manner that at least one persistent recess (11, 18, 19) is formed which uncovers at least one current diverter (7) of the battery, and

(ix) Sealing of the recess(es) (11, 18, 19) with a electrically conductive material.

21. Method according to claim 20, characterized in that a structured layer of electrically conductive material is deposited on at least one recess(es) (11, 18, 19) which is sealed with electrically conductive material in such a manner that this material forms a conductive contact between the (single) recess or those recesses which are in contact with the current diverters (7) with counter polarity of the battery contact (2a), and the separated battery contact (2b).

22. Method according to claim 21, wherein the steps (iii) to (vi) are performed simultaneously or subsequently several times in such a manner that each a current diverter is positioned between two rectified electrodes and a separator/electrolyte layer is positioned between two counter directed electrodes, wherein the removal of material of covering layer(s) according to step (viii) is performed in such a manner that substantially all current diverters (7) of the battery are uncovered, so that subsequently all recess(es) (18, 19) can be sealed according to step (ix) with an electrically conductive material and that a conductive contact (11) between all current diverters which are in contact with electrodes of equal polarity, and the corresponding battery contact (2a, 2b), and/or one of both feedthrough(s) (3) is achieved.

23. Method according to claim 22, characterized in that the sealing of the recesses (18, 19) and the manufacture of a conductive contact (11) is performed in subsequent steps or in a single step by applying a structured metallization.

24. Method according to one of the claims 20 to 23, characterized in that the battery contact layer (2) is deposited by deposition of metal from the gas phase and especially by vacuum deposition.

25. Method according to claim 24, characterized in that the battery contact layer (2) is deposited in a structured manner or is structured after its deposition so that it forms beside the mentioned battery contact (2a) a second battery contact (2b) for the counter electrode which is separated from the mentioned battery contact, which is outside the encapsulation, wherein as substrate (1) a substrate is used which has feedthroughs (3) which are arranged in such a manner that they lead away from both battery contacts (2a, 2b) through the substrate.

26. Method for manufacturing a plurality of batteries according to one of the claims 16 or 17 comprising the following steps:

(i) Providing a substrate (1),

(ii) Applying a structured battery contact layer with each two contacts (2a, 2b) per battery on the substrate (1),

(iii) Applying a structured electrode layer with each an electrode surface (4) per battery,

(iv) Applying a structured separator/electrolyte layer with each a separator/electrolyte surface (5) per battery in such a manner that they cover substantially or exactly or extend slightly over these electrode surfaces (4) of the layer of step (iii),

(v) Applying a structured counter electrode layer with each an electrode surface (6) per battery in such a manner that they cover substantially or exactly or extend in comparison to them slightly before the separator/electrolyte layers (5) of the layer of step (iv),

(vi) Applying a structured current diverter layer with each a current diverter surface (7) per battery in such a manner that they cover substantially or exactly or extend slightly over the underlying electrode surface (4, 6),

wherein the steps (ii) to (vi) can be performed subsequently or simultaneously or wherein at first step (ii) and then at the same time steps (iii) to (vi) may be performed, or wherein at first step (ii) is performed and then the steps (iii) to (vi) are repeated several times simultaneously or subsequently in suitable order,

(vii) Applying a first covering layer (8, 16, 17, 21) of a first electrically insulating material that is stable in relation to the used electrolyte and electrode material from the gas phase or in form of a liquid or viscous paste and optionally a second covering layer of either a material as defined for the first covering layer or a second electrically

conductive material which was also deposited from the gas phase or in form of a liquid or viscous paste, and optionally further covering layers of the first or the second material in such a manner that these covering layer(s) form(s) together with the substrate und optionally (a) further component(s) a separate encapsulation for each battery through which the batteries are sealed from the surrounding environment,

(viii) Removing material of the covering layer(s) in such a manner that at least one persistent recess (11, 18, 19) is formed per battery which uncovers at least one current diverter (7) of the battery, and

(ix) Sealing of the recess(es) (11, 18, 19) with an electrically conductive material.

27. Method according to one of the claims 20 to 26, characterized in that a part of or all steps (iii) to (vi) are performed by depositing prestructured materials which are provided on a support carrier.

28. Method according to claim 27, characterized in that the prestructured materials are deposited on the support carrier by means of a printing method or by means of lithographic methods and etching methods or were structured on the support carrier by means of methods such as laser structuring, water jet processing or mechanical removal.

29. Method according to one of the claims 26 to 28, characterized in that the removal is performed mechanically by generating persistent channels (19), wherein each channel uncovers simultaneously several current diverters (7).

30. Method according to one of the claims 20 to 26, characterized in that a part of or all steps (iii) to (vi) are performed by applying persistent layers which are structured after the application.

31. Method according to claim 30, characterized in that the structurings are performed by means of lithographic methods, etching methods and/or pattern processes.

32. Method according to claim 30, characterized in that the persistent layers are applied lying on a support carrier and then this is removed.

33. Method according to claim 30, characterized in that the materials of the layers (4, 5, 6 and/or 7) are selfsupporting foils.

34. Method according to one of the claims 20 to 33, wherein the layers (4, 5, 6 and/or 7) are laminated on.

35. Method according to claim 24 or 25, characterized in that the structuring of the battery contact layer (2) is performed by means of a mechanical method such as water jet processing, by laser processing, chemically by chemical etching, by galvanic methods and/or by means of patterns.

36. Method according to one of the claims 20 to 35, characterized in that prior to applying the first covering layer a drying is performed in an inert gas oven or under vacuum.

37. Method according to one of the claims 20 to 36, characterized in that the separator/electrolyte layer and if necessary the electrode layers are filled with electrolyte fluid and the battery is formed prior to encapsulation.

38. Method according to one of the claims 20 to 36, characterized in that besides the removal of material of the covering layer(s) according to step (vii) for uncovering of at least one current diverter further material is removed from this/these layer(s) in such a manner that an uncovering of the separator/electrolyte layer is performed, wherein the uncovered separator/electrolyte layer is filled with electrolyte fluid and the recess(es) formed by the removal is/are then sealed again.

39. Method according to one of the claims 20 to 36, characterized in that the separator/electrolyte layer is filled with electrolyte fluid via a channel (30) in the substrate (1) and then the channel (30) is sealed whereupon the battery is formed.

40. Method according to one of the claims 20 to 39, characterized in that the removal of material of the covering layer(s) according to step (vii) is performed by means of plasma-enhanced methods, especially reactive ion etching or ion

bombardment, by wet-chemical etching, by laser processing or by a mechanical method such as sawing, milling or water jet processing, wherein the etching methods comprise a lithography step for transferring the contact image.

41. Method of manufacturing a battery according to one of the claims 1 to 15, characterized in that by means of the method according to one of the claims 26 to 40 a plurality of batteries is manufactured and that these are then isolated by separating the substrate between the batteries.

Figures

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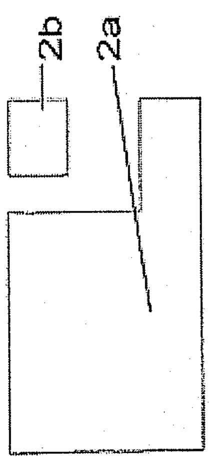

Figure 1a

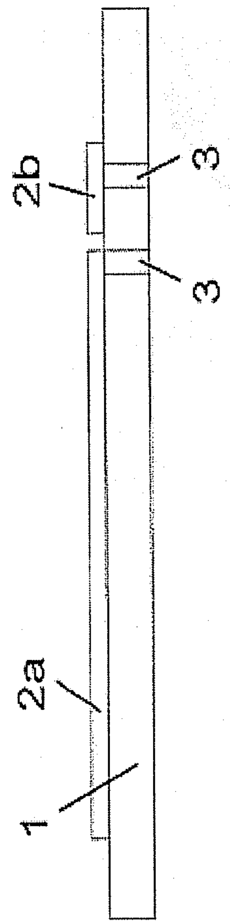

Figure 1b

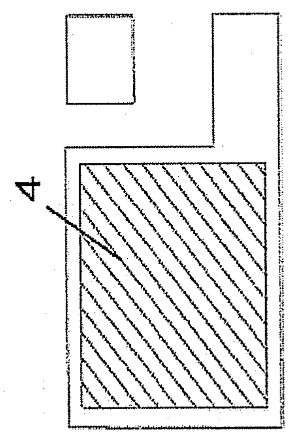

Figure 2a

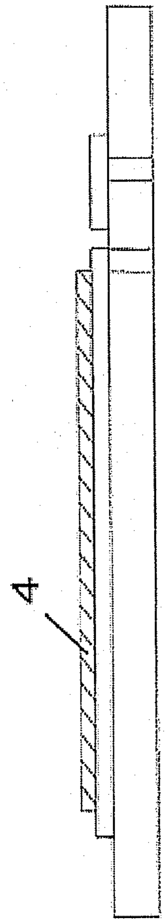

Figure 2b

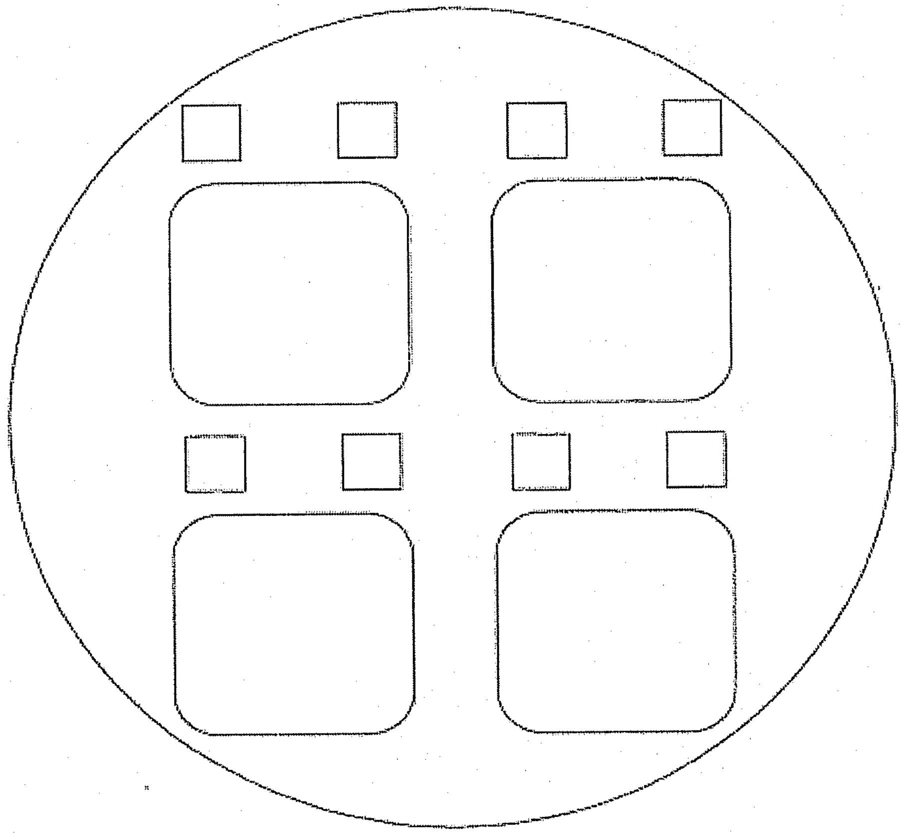

Figure 1c

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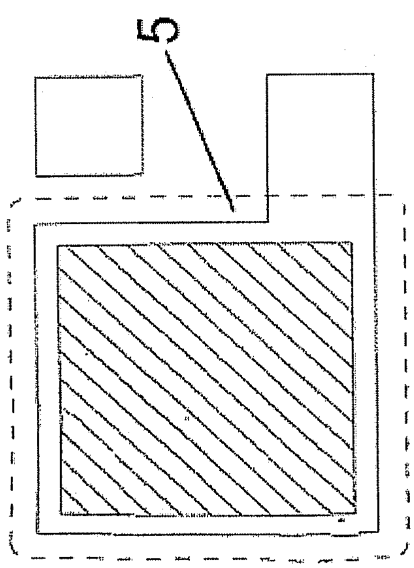

Figure 3a

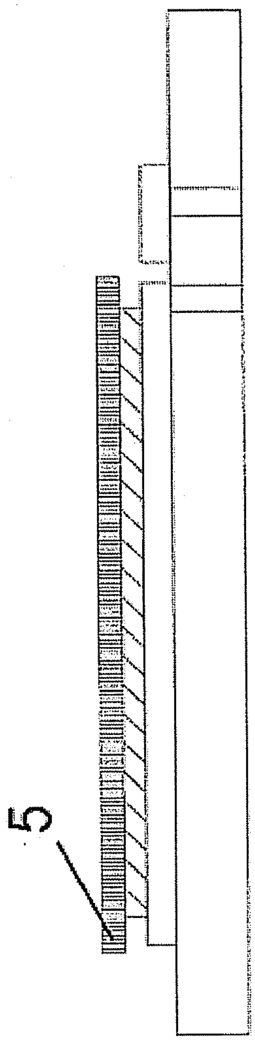

Figure 3b

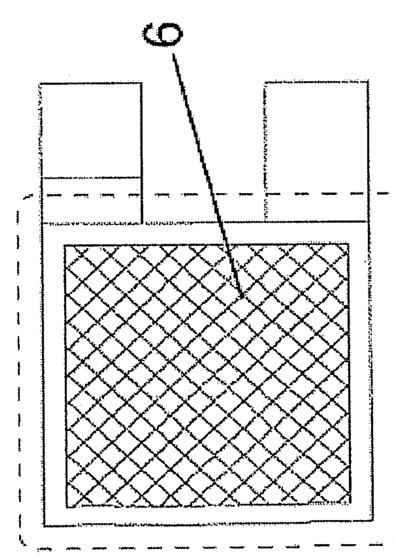

Figure 4a

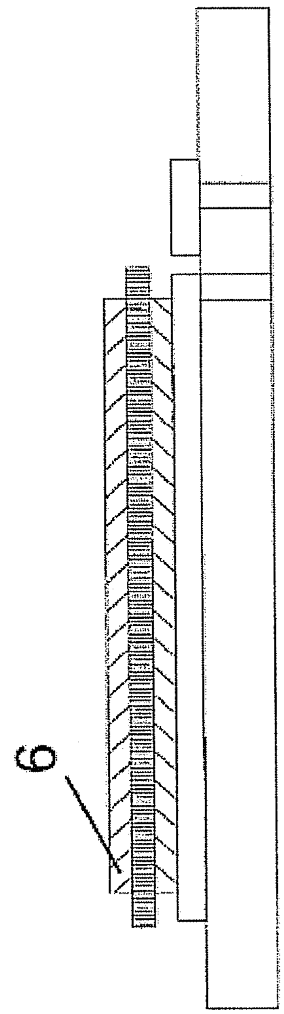

Figure 4b

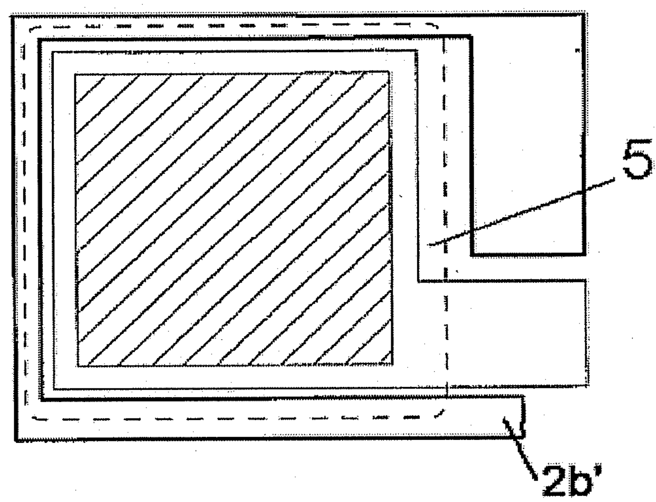

Figure 3C

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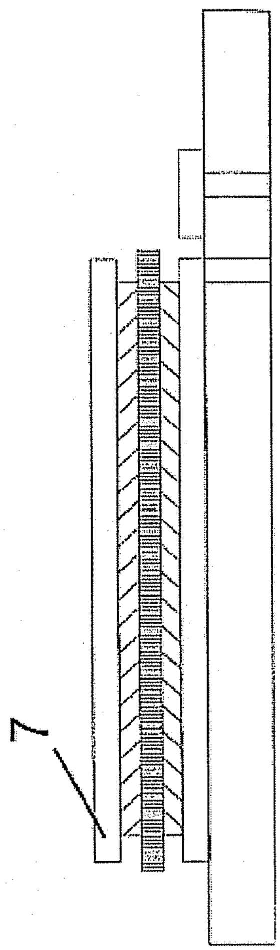

Figure 5b

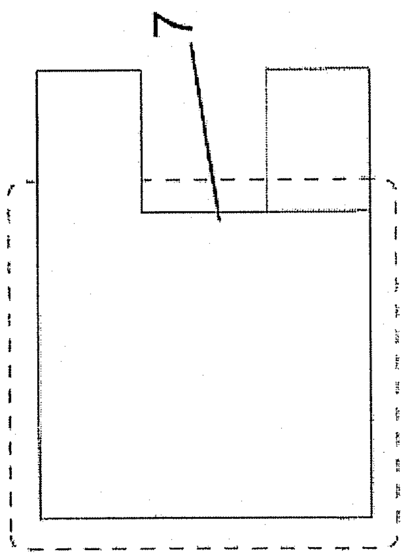

Figure 5a

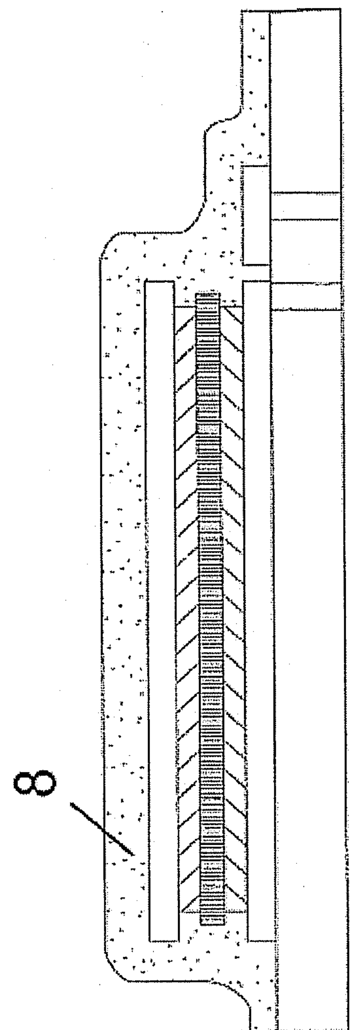

Figure 6b

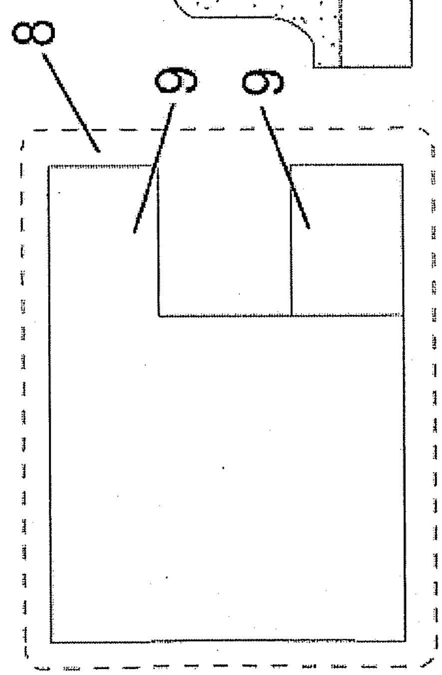

Figure 6a

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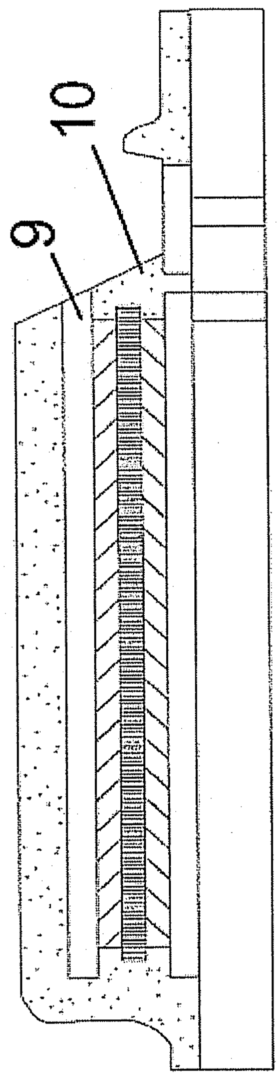

Figure 7a

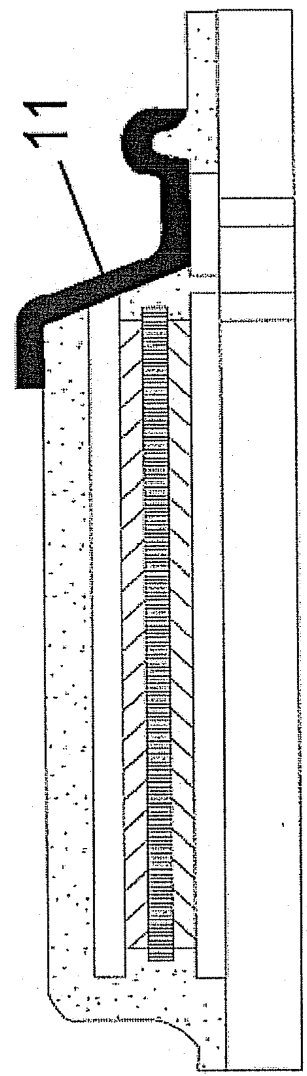

Figure 8a

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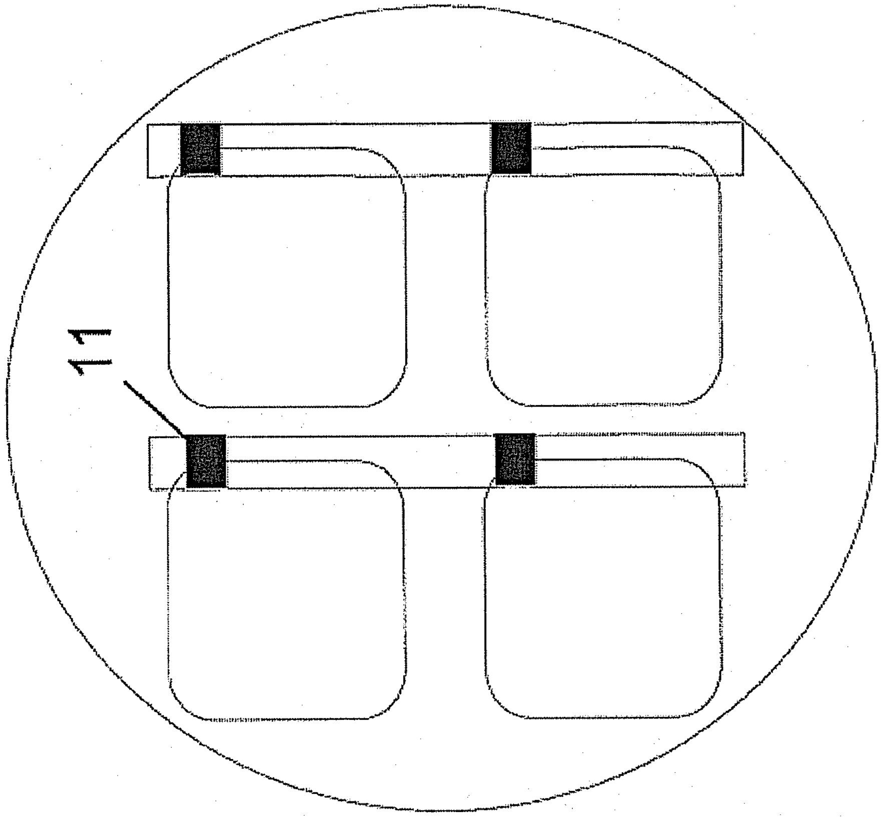

Figure 8b

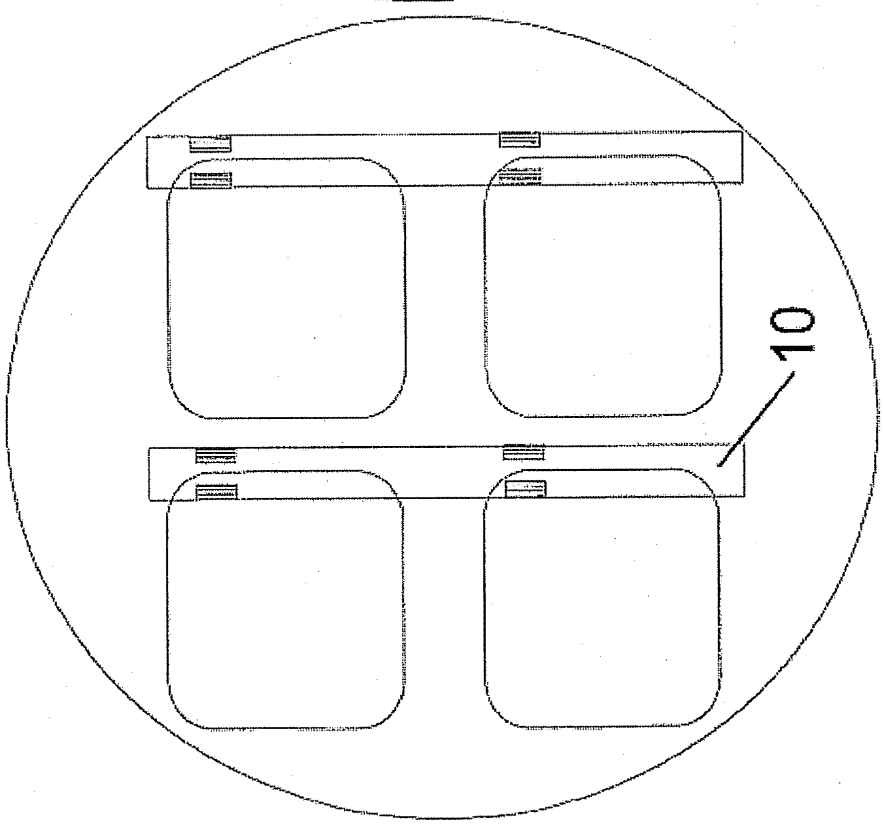

Figure 7b

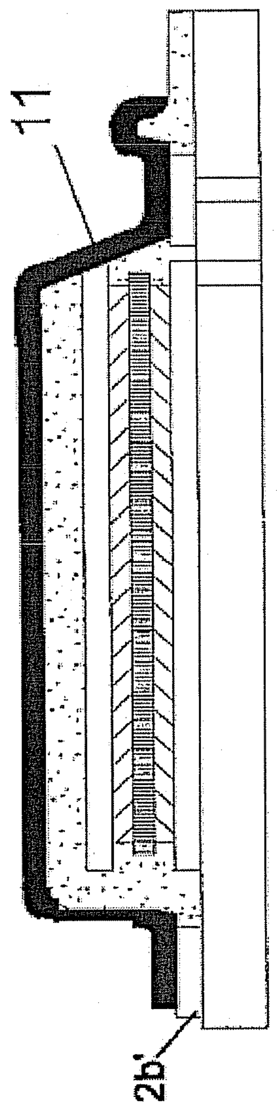

Figure 8c

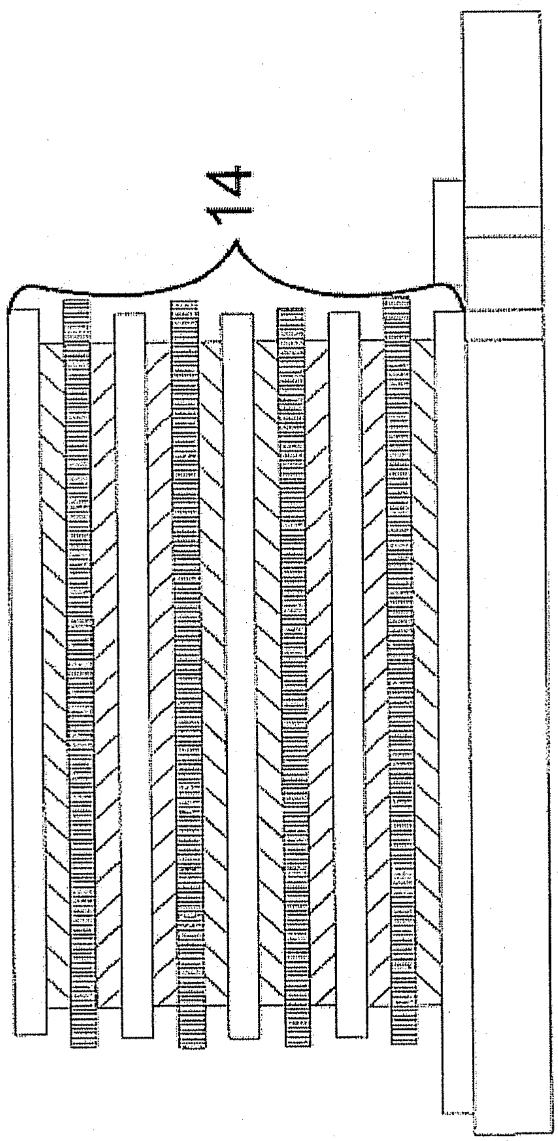

Figure 9a

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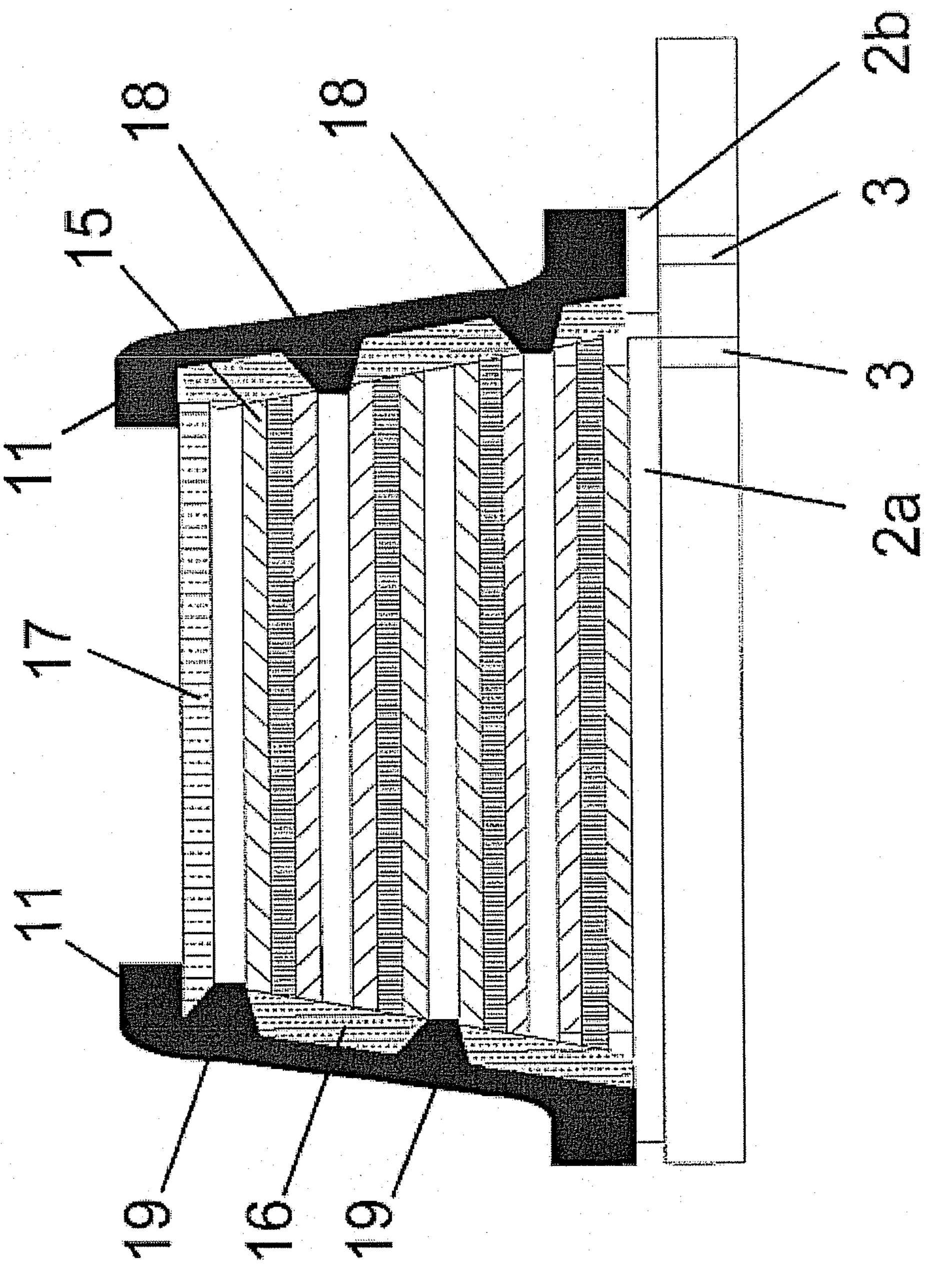

Figure 9b

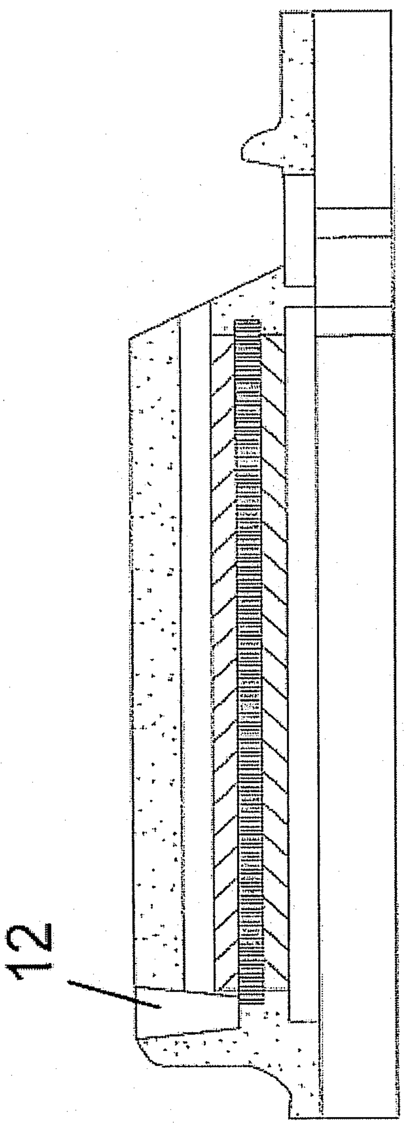

Figure 10a

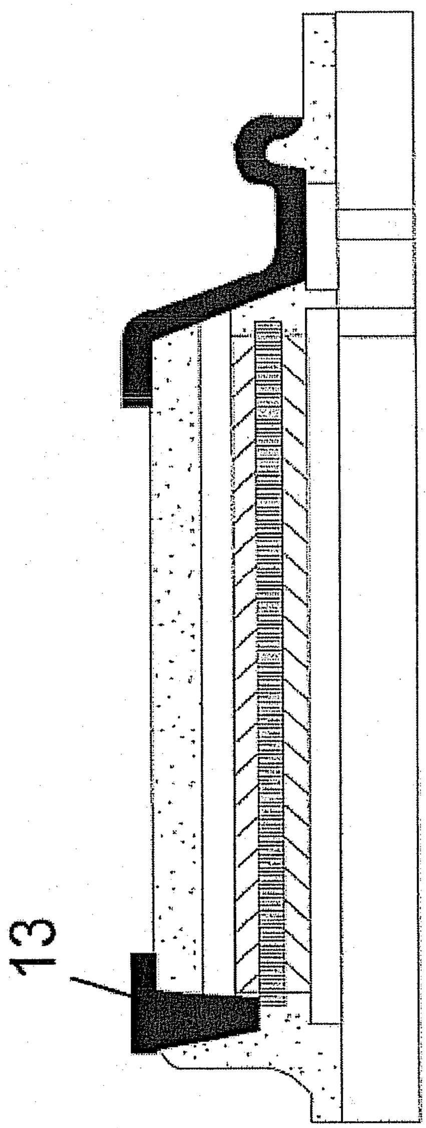

Figure 10b

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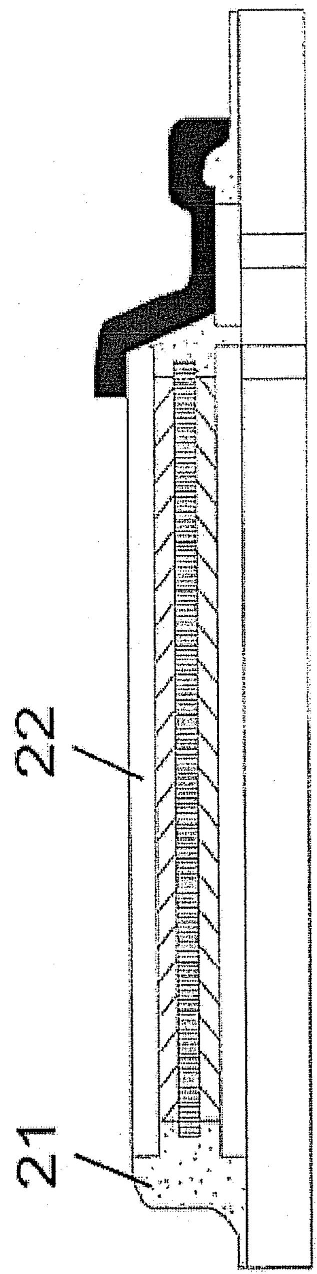

Figure 11

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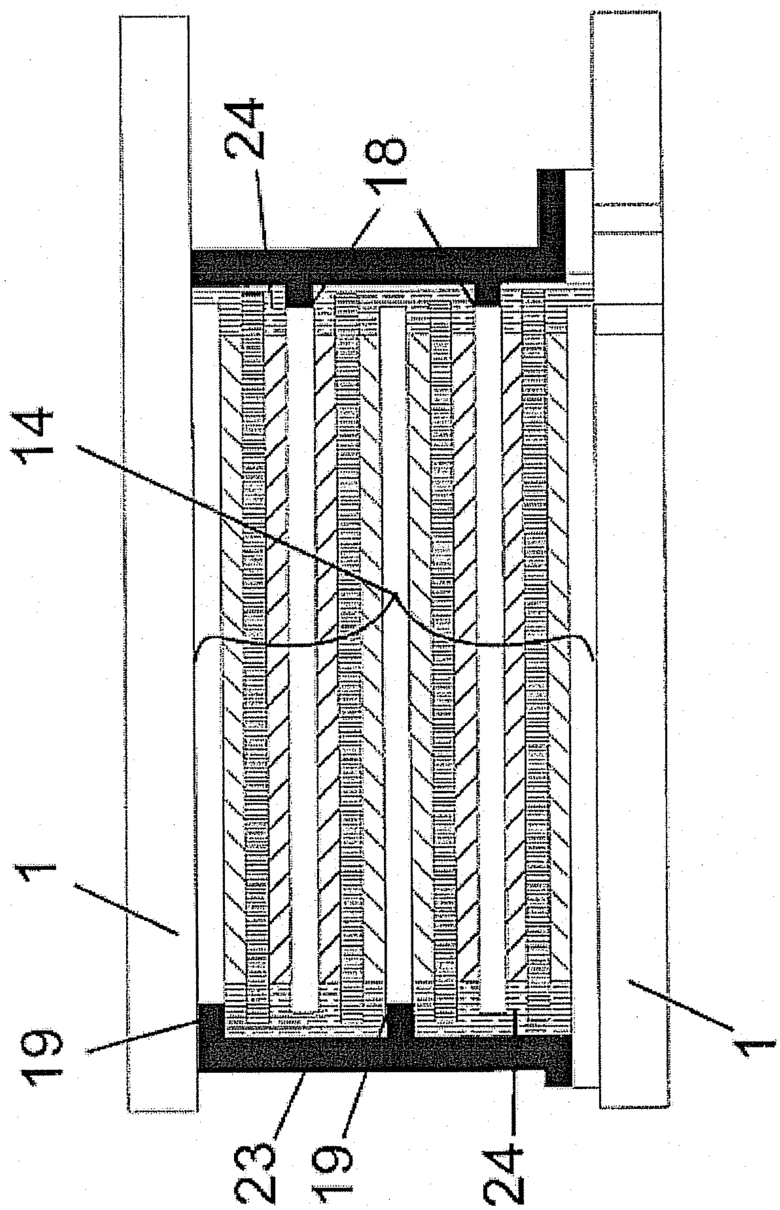

Figure 12

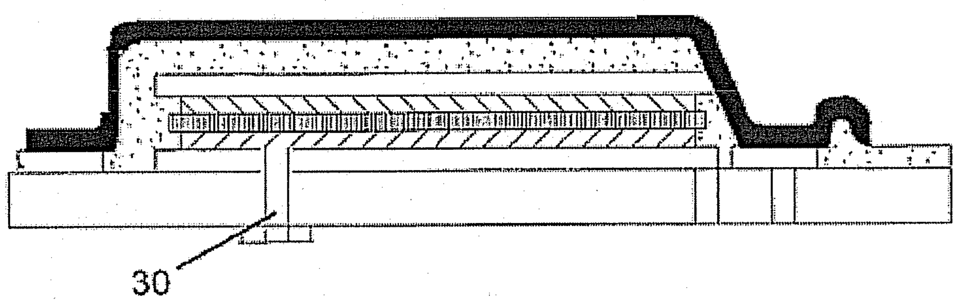

Figure 13a

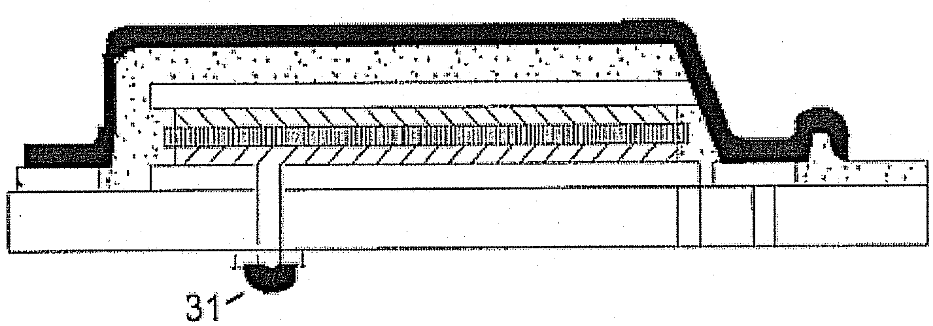

Figure 13b